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Design and status of COMPASS FAST-RICH

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Abstract

In the context of the upgrade of COMPASS RICH-1, we are developing a fast photodetection system for RICH counters, based on UV extended Multi-Anode PhotoMultiplier Tubes (MAPMT) and a custom, low dead-time electronic readout system. Photons are concentrated on the MAPMT photocathode by an optical system that preserves the position information. The ratio between the collection and the photosensitive surfaces is ~7.5 in our design, larger than in previous applications. A new front-end electronics, based on a modified version of the MAD4 discriminator chip, is being realized to digitize the MAPMT signals. We report about the design of the photodetection system and of the associated electronic readout system, and on the preliminary test beam results.

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1. Introduction

Particle identification at high rates and in high multiplicity environments is a crucial aspect of many modern

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and future high energy experiments. The upgrade of the detector RICH-1 [1] of the COMPASS experiment [2] at CERN SPS requires, in the detector central region, photon detection technology and an associated electronic readout system that allow trigger rates in the 100 kHz range and single channel counting rates of several MHz. Such demanding requirements can be fulfilled by a Ring Image Cherenkov (RICH) detector, equipped with Multi Anode Photomultipliers (MAPMT) and fast, pipelined, low dead-time readout electronics. The ratio between the photon collection and photon detection surfaces is made larger than 7 by introducing a photon condensation optics. In order to keep the overall cost affordable, in our design this ratio is larger than similar implemented [3] or proposed [4] systems, where it was <3. Outside RICH-1 central region, where the single channel counting rates are lower, an upgrade of the readout system of the present photon detectors is foreseen [5].

We present the design of a fast photon detection system fulfilling the mentioned requirements (Section 2), the most relevant test beam result obtained with a prototype setup (Section 3), and the design of the optical system (Section 4).

2. The photon detection system and the associated readout electronics

The system is based on the MAPMT R7600-03-M16 by Hamamatsu,[1] characterized by a bialkali photocathode with $18 \times 18\,\mathrm{mm}^2$ active surface and 16 pixels. They have extended UV glass entrance window to increase the range of detectable Cherenkov photons (200–600 nm). The MAPMTs have been equipped with thin home made resistive divider boards. The careful design of the internal PCB ground layers and the application of an external black varnish ensure light tightness on the back side of the device. The MAD4 discriminator chip [6] is used to digitize the photomultiplier signal. A modified version of this chip (CMAD) is being developed; the main goals are the ability to provide individual threshold settings for each channel and single channel rate capabilities up to 5 MHz. To minimize the noise at the input stage, the preamplifier/discriminators are housed on small PCB boards directly connected to the resistive dividers. The hit time measurement and data transmission are performed by a digital readout board based on the F1 TDC chips [7], providing a time resolution better than 130 ps. The hit information is formatted by the TDC chips into 24-bits data words, and transmitted out through a 400 Mb/s fast serial connection. A deck board connects one TDC board to 64 discriminator channels (4 MAPMT), and provides the distribution of the supply and threshold voltages to the discriminator boards. The arrangement described here avoids the use of cables up to the data transmission out of the TDC boards, resulting in a compact readout system.

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3. Testbeam results

The proposed design has been studied and validated in two test beam exercises at the T11 beam line of the CERN PS accelerator facility, during years 2003 and 2004. In the following, the setup of the 2004 test beam will be described, and the most relevant results will be discussed.

The setup is schematically shown in Fig. 1. A far Cherenkov photon source is simulated by placing a fused silica radiator, shaped as a truncated cone, in the focus of a UV parabolic mirror. The angle of the cone surface is such that, at saturation, the Cherenkov photons produced by particles flying parallel to the cone axis are not deflected at the exit of the radiator piece. The angle at which the photons are reflected by the mirror can be varied by adjusting the relative position of the radiator and the mirror itself. A movable aluminium tube surrounding the radiator allowed to precisely tune the amount of Cherenkov photons reaching the MAPMTs. The Cherenkov photons are concentrated onto the MAPMT sensitive surface using single, thick fused silica lenses (an arrangement substantially different from the final design of the optical system discussed in Section 4). An aluminium panel, placed at about 50 cm from the radiator, provides the mechanical fixation for the lenses and the MAPMT. Eight lens and MAPMT blocks are mounted in a circular pattern, so that they intercept the reflected Cherenkov photons. The ring image produced by the Cherenkov photons is clearly visible as an enhancement in the counting rate by the corresponding MAPMT pixels. The typical hit multiplicity distributions of the MAPMTs are accurately reproduced by our Monte Carlo simulations of the test beam setup, while absolute rate estimations are accurate at 10% level. The threshold curves at nominal high voltage (see Fig. 2-left) clearly show the presence of a wide range of threshold values for which the electronics noise and the cross-talk are rejected, without losses of the single photoelectron efficiency. The probability for each pixel to be fired in combination with a reference one (see Fig. 2-right) has been measured in order to estimate the overall cross-talk of the photon detection system. The highest cross-talk probability is indeed associated to the pixels surrounding the reference one.

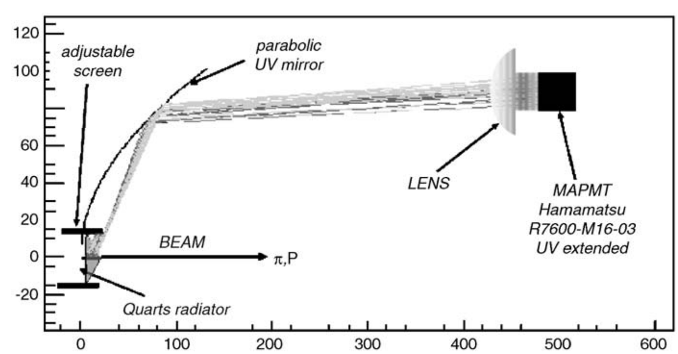

Fig. 1. Schematic view of the 2004 test beam setup.